

## IMPROVED PROCESS FOR THE PREPARATION OF STABILIZED POLYALKENYL SULFONIC ACIDS

## BACKGROUND OF THE INVENTION

## Field of the Invention

8 Sulfonates are a class of chemicals used in household, industrial, and  
9 institutional cleaning applications; personal care and agricultural products;  
10 metalworking fluids; industrial processes; emulsifying agents; corrosion  
11 inhibitors and as additives in lubricating oils. Some of the desirable properties  
12 of sulfonates for use in lubricating oil applications include their low cost,  
13 compatibility, water tolerance, corrosion inhibition, emulsion performance,  
14 friction properties, high temperature stability, rust performance, and light color.

16 Sulfonates used in lubricating oil applications have been classified as either  
17 neutral, low overbased (LOB) sulfonates, or high overbased (HOB)  
18 sulfonates.

20 In the past, lubricating oil sulfonates, called natural sulfonates, were made as  
21 a by-product of white oil and process oil production. More recently, due to the  
22 desire for higher utilization of raw materials and hence improved economics,  
23 synthetic sulfonates, derived from alkyl aromatic feedstocks, have increased  
24 in use. Unfortunately, synthetic sulfonates can have inferior performance  
25 properties compared to natural sulfonates and thus the search for economical  
26 viable sulfonates with performance properties more like natural sulfonates is  
27 an area of continuing research.

29 Polyalkenyl sulfonates are a class of sulfonates that have desirable  
30 performance properties in lubricating oil applications. One of the most  
31 commonly employed sulfonation technologies utilizes a mixture of sulfur  
32 trioxide  $\text{SO}_3$  and air ( $\text{SO}_3/\text{Air}$ ). The production of polyalkenyl sulfonic acids is

1 most economically achieved by sulfonating a polyalkene with SO<sub>3</sub> gas in a  
2 gas/liquid reaction. When a polyalkene reacts with sulfur trioxide (SO<sub>3</sub>) in a  
3 gas/liquid reaction, undesirable side reactions occur that reduce the quality  
4 and quantity of the desired polyalkenyl sulfonic acid. There are three primary  
5 side reactions that occur most predominantly: (1) the degradation of the  
6 polyalkenyl sulfonic acid; (2) the formation of sultone molecules; and (3) the  
7 formation of lower molecular weight polyalkenyl sulfonic acids from  
8 fragmentation reactions. The degradation of the polyalkenyl sulfonic acid  
9 lowers the yield of the desired polyalkenyl sulfonic acid, as does the formation  
10 of sultones. The fragmentation of the polyalkenyl sulfonic acid molecule  
11 results in undesirable short-chained sulfonic acids. Usually, sulfonic acids  
12 may be overbased to prepare sulfonates that are useful for the  
13 aforementioned applications; however, a low yield of sulfonic acids results in a  
14 low yield of the sulfonate product.

15  
16 An improved process for producing polyalkenyl sulfonic acids in a polyalkene-  
17 sulfur trioxide gas/liquid reaction, which decreases the degradation reactions  
18 of the polyalkene sulfonic acid and the formation of sultones and  
19 fragmentation products and stabilizes the polyalkenyl sulfonic acid product,  
20 has now been discovered.

21  
22 An advantage of this improved process is the reduction of fragmentation  
23 reactions that produce lower molecular weight sulfonic acid and the reduction  
24 of sultone formation, as well as an increase in the quantity of the resulting  
25 sulfonates prepared from the polyalkenyl sulfonic acid.

26

27 Description of the Related Art

28

29 Harrison et al., U.S. Patent No. 6,410,491, disclose a method of making  
30 polyalkenyl sulfonates wherein the polyalkenyl sulfonic acid is derived from a  
31 mixture of polyalkenes comprising greater than 20 mole percent alkyl  
32 vinylidene and 1,1-dialkyl isomers and a method for making the same.

1 Le Coent, U.S. Patent No. 4,764,295, discloses non-foaming detergent-  
2 dispersant additives and the method of making such additives from  
3 alkaryl sulfonates of alkaline earth metals.  
4

5 Alcock et al., U.S. Patent No. 5,789,615, disclose a method of making  
6 sulfonates by adding sulfonic acid to a dispersion of basic hydroxide or oxide  
7 in a water/diluent mixture to form a reaction mixture. Sulfonic acid is added in  
8 stages during the reaction to maintain the basicity of the reaction mixture.  
9

10 Karll et al., U.S. Patent No. 3,954,849, disclose a method of making alkenyl  
11 sulfonates by reacting propene or butene polymers having a number average  
12 molecular weight of about 250-500 with gaseous sulfur trioxide in falling-film  
13 or static reactors. A two-stage neutralization of the sulfonation product with  
14 ammonia or sodium hydroxide is used to reduce sulfone content and increase  
15 the sulfonate in the neutralized product.  
16

17 Rath, U.S. Patent No. 5,408,018, discloses a method for preparing highly  
18 reactive polyisobutenes containing more than 80 mole percent terminal  
19 vinylidene groups and having an average molecular weight of 500 to 5,000  
20 Dalton.  
21

22 The Related Art, Harrison et al., U.S. Patent No. 6,410,491; Le Coent, U.S.  
23 Patent No. 4,764,295; Alcock et al., U.S. Patent No. 5,789,615; Karll et al.,  
24 U.S. Patent No. 3,954,849; and Rath, U.S. Patent No. 5,408,018, are herein  
25 incorporated by reference.  
26

27 SUMMARY OF THE INVENTION  
28

29 The present invention provides an improved process for making polyalkenyl  
30 sulfonic acids and the corresponding overbased sulfonates. The improved  
31 process increases the yield of long-chain polyalkenyl sulfonic acid by

1 stabilizing the polyalkenyl sulfonic acids and decreasing the amount of sultone  
2 formation and fragmentation reactions.

3

4 Accordingly, in one aspect, the present invention is directed to a process for  
5 making a stabilized polyalkenyl sulfonic acid comprising:

6

7 (a) reacting a polyalkene with  $\text{SO}_3$  in a first reaction vessel; and

8

9 (b) stabilizing the product of step (a) by neutralizing with a neutralizing  
10 agent as the product of step (a) exits the first reaction vessel and prior to  
11 or concurrently with entering a second vessel for further reaction or  
12 storage, wherein neutralization occurs in the absence of ammonia or  
13 sodium hydroxide and wherein the neutralizing agent is an alkaline earth  
14 metal hydroxide.

15

16 In another aspect, the present invention is directed to a process for  
17 overbasing polyalkenyl sulfonic acid with an alkaline earth metal and wherein  
18 water is used as a promoter.

19

20 BRIEF DESCRIPTION OF DRAWINGS

21

22 Figure 1 depicts the % Ca as Sulfonate and % Sulfuric Acid levels determined  
23 by the Cyclohexylamine titration method for an unstabilized PIB sulfonic acid  
24 prepared by the  $\text{SO}_3/\text{Air}$  sulfonation of 550 MW PIB as a function of time when  
25 stored at 40°C (104°F).

26

27 Figure 2 depicts the % Ca Sulfonate determined by the Hyamine titration  
28 method of an unstabilized PIB sulfonic acid stored at 40°C (104°F) and 60°C  
29 (140°F).

30

31 Figure 3 depicts the % Ca Sulfonate (determined by the Hyamine titration  
32 method) for PIB Sulfonic acid prepared by  $\text{SO}_3/\text{Air}$  sulfonation followed by

1 stabilization of the PIB sulfonic acid by neutralization (with lime slurry) as a  
2 function of time when stored at 40°C (104°F) and 60°C (140°F).

3

4 Figure 4 depicts the negative ion electrospray mass spectrum (ESMS) of an  
5 unstabilized 550 MW polyisobutene sulfonic acid produced by SO<sub>3</sub>/Air  
6 sulfonation.

7

8 Figure 5 depicts the negative ion electrospray mass spectrum (ESMS) of a  
9 550 MW PIB sulfonic acid stabilized by neutralization with a slurry of lime in  
10 oil.

11

12 DETAILED DESCRIPTION OF THE INVENTION

13

14 Definitions

15

16 Unless specifically stated otherwise, the following terms will have the following  
17 meaning:

18

19 "PIB" — Polyisobutene having a number average molecular weight of from  
20 about 300 to about 1000 unless otherwise stated.

21

22 "% Ca as Sulfonate" is determined by titration using the analytical technique  
23 referred to as the Cyclohexylamine Titration.

24

25 "% Sulfonic Acid" is determined by titration using the analytical technique  
26 referred to as the Cyclohexylamine Titration.

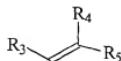
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28 "% Ca Sulfonate" is determined by titration using the analytical technique  
29 referred to as the Hyamine Titration.

30

31 "% Hyamine Actives" or "% Hyamine Active Technique (HAT)" is determined  
32 by titration using the analytical technique referred to as the Hyamine Titration.

1 "Low overbased" — TBN from about 0 to about 100.  
2  
3 "Moderate overbased" — TBN from about 101 to about 250.  
4  
5 "High overbased" — TBN from about 251 to about 400.  
6  
7 "High high overbased" — TBN greater than about 400.  
8  
9 "TBN" is an analytical titration measurement and refers to Total Base Number  
10 and equals the milliequivalents of KOH per gram of sample being titrated.  
11  
12 The term "alkylvinylidene isomer" refers to a formula of the structure:  
13



1 The term "degree of neutralization" refers to the number of mole equivalents  
2 of the neutralizing agent divided by the number of moles of acid times 100.

3

4 Sulfonation

5

6 The polyalkenyl sulfonic acid product of the present invention is stable to  
7 degradation with time and temperature and also contains a small amount of  
8 sultones and a decreased amount of fragmentation products which would  
9 normally form during SO<sub>3</sub>/air sulfonations. Typically, the product of the  
10 present invention is a mixture of polyalkenyl sulfonic acid, sulfuric acid,  
11 recovered polyalkene, sultones, and sulfur trioxide. The mixture also  
12 comprises lower molecular weight fragmentation products of the polyalkenyl  
13 sulfonic acids. In accordance with the present invention, decreased amounts  
14 of sultones and fragmentation products can be achieved by stabilizing the  
15 reaction product of the polyalkene and SO<sub>3</sub> reaction by neutralizing the  
16 product as it exits a first reaction vessel and prior to or concurrently with  
17 entering a second vessel which is used for further reaction or storage. At  
18 least one of the following steps in the process of making polyalkenyl sulfonic  
19 acid may be additionally employed: using optimum sulfonation conditions,  
20 diluting the polyalkene feedstock, and adding carboxylic acid to the  
21 polyalkene feedstock.

22

23 In the present invention, polyalkylenes, typically derived from C<sub>2</sub>-C<sub>6</sub> olefins  
24 and preferably polyisobutene (PIB), are the starting materials used for the  
25 reaction with sulfur trioxide. The reaction is a gas-liquid reaction that occurs  
26 either in a continuous process (e.g., falling film reactor) or in a batch process.  
27 The reaction of polyalkene with sulfur trioxide may be carried out in a manner  
28 that is well known. Preferably, the reaction of polyalkene and sulfur trioxide is  
29 accomplished by reacting a mixture of polyalkenes comprising greater than  
30 20 mole percent alkyl vinylidene and 1,1-dialkyl isomers with a source of one  
31 of the following: sulfur trioxide and air, sulfur trioxide hydrates, sulfur trioxide  
32 amine complexes, sulfur trioxide ether complexes, sulfur trioxide phosphate

1    complexes, acetyl sulfate, a mixture of sulfur trioxide and acetic acid, sulfamic  
2    acid, alkyl sulfates or chlorosulfonic acid. More preferably, the mixture of  
3    polyalkenes comprises polyisobutenes having a number average molecular  
4    weight of about 300 to about 1000, preferably about 300 to about 750, more  
5    preferably about 350 to about 600, and even more preferably about 350 to  
6    about 550. Most preferred are polyisobutenes having a methylvinylidene  
7    content of greater than 20%, preferably greater than 50%, and more  
8    preferably greater than 70%, and a number average molecular weight of  
9    preferably about 350 to about 600 and even more preferably about 350 to  
10   about 550.

11   Rath, U.S. Patent No. 5,408,018, which issued on April 18, 1995, and which is  
12   incorporated by reference in its entirety, and the references cited therein,  
13   describe a suitable process for the production of polyisobutenes that contain  
14   greater than 80 mole percent terminal vinylidene groups.

15

16   The polyalkenes, preferably derived from C<sub>2</sub>-C<sub>6</sub> olefins, used to prepare the  
17   polyalkenyl sulfonic acid are typically a mixture of polyalkenes having a  
18   molecular weight of about 300 to about 1000. Preferably, the polyalkenes are  
19   derived from lower alkene monomers such as ethylene, propylene, butylenes,  
20   pentene and hexene. More preferably, the polyalkene is polyisobutene (PIB).  
21   The polyalkene or mixture of polyalkenes, such as polyisobutene, preferably  
22   comprises greater than 20 mole percent, more preferably greater than  
23   50 mole percent, and most preferably greater than 70 mole percent alkyl  
24   vinylidene and 1,1-dialkyl isomers. The preferred alkylvinylidene isomer is a  
25   methyl vinylidene isomer and the preferred 1,1-dialkyl isomer is a 1,1-dimethyl  
26   isomer.

27

28   When polyisobutene having a mole percent of alkyl vinylidene and 1,1-dialkyl  
29   isomers greater than 20% is used to prepare polyisobutenyl sulfonic acids or  
30   sulfonates, the molecular weight distribution of the resulting product has at  
31   least 80% of the polyisobutenyl sulfonic acids or sulfonates whose molecular

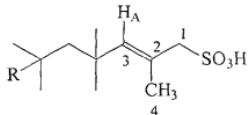
1 weights are separated by even multiples of 56 daltons. In other words, less  
2 than 20% of the polyisobutyl sulfonic acids or sulfonates in the molecular  
3 weight distribution of the sulfonic acids or sulfonates contain a total number of  
4 carbon atoms that is not evenly divisible by four. Preferably, the  
5 polyisobutyl sulfonic acids prepared by the process of the present invention  
6 have molecular weights which are separated by even multiples of 56 daltons.  
7

8 The reaction of the polyalkene, such as polyisobutene, and sulfur trioxide may  
9 occur in either a reaction vessel, such as a falling film reactor or a batch  
10 reactor. A preferred source of SO<sub>3</sub> is the product resulting from reacting an  
11 intermediate product, SO<sub>2</sub>, with air over a catalyst. If the reaction occurs in a  
12 falling film reactor, polyisobutene is reacted with SO<sub>3</sub> in the presence of air  
13 where the polyisobutene is distributed on a surface as a thin film. This  
14 distribution of polyisobutene allows for both efficient contacting with SO<sub>3</sub> and  
15 removal of the heat of reaction. If the reaction occurs in a batch reactor,  
16 polyisobutene is reacted with SO<sub>3</sub> in the presence of air in a vessel where the  
17 rate of addition of the SO<sub>3</sub> is more critical in controlling reaction temperatures.  
18 The preferred source of SO<sub>3</sub> is a mixture of sulfur trioxide and air.  
19

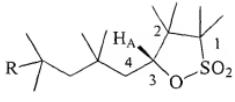
20 When used herein, the term "polyisobutene" or "PIB" is used as an example of  
21 the polyalkene employed in the present invention.  
22

23 In one embodiment of the present invention, polyalkene, preferably  
24 polyisobutene, having a number average molecular weight of from about 300  
25 to about 1000, is reacted with a source of sulfur trioxide under reactive  
26 conditions. The reaction effluent, containing a mixture of PIB sulfonic acid,  
27 sulfuric acid, recovered PIB, lower molecular weight PIB sulfonic acids,  
28 sulfones and sulfur trioxide, continues to react even at ambient temperatures.  
29 The quantity of sulfonic acid decreases and the quantity of sulfones, which  
30 comprises a mixture of gamma and delta isomers, increases.  
31

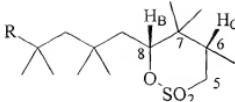
1 The reaction of PIB with  $\text{SO}_3$  produces a mixture comprising PIB sulfonic  
2 acids, PIB sultones, and recovered PIB. The PIB sulfonic acids have the  
3 following structure where R is the polybutene tail:  
4



5 1  
6  
7 This product can be characterized by  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectroscopy. The  
8 chemical shifts for the PIB sulfonic acid 1 (dissolved in  $\text{CDCl}_3$ ) are assigned  
9 as follows:  $^1\text{H}$  NMR; 5.58 ppm (singlet, 1H, vinyl proton  $\text{H}_\text{A}$ ), 3.71 ppm  
10 (singlet, 2H, protons on carbon atom  $\text{C}_1$  alpha to the  $\text{SO}_3\text{H}$  group), 1.94 ppm  
11 (singlet, 3H, methyl protons on carbon  $\text{C}_4$ );  $^{13}\text{C}$  NMR; 120.0 ppm (olefin  
12 carbon  $\text{C}_2$ ), 147.1 ppm (olefin carbon  $\text{C}_3$ ), 63.8 ppm (carbon  $\text{C}_1$  alpha to the  
13  $\text{SO}_3\text{H}$  group). Minor amounts of other PIB sulfonic acids of different  
14 structures may also be present in the mixture.  
15  
16 The molecular weight distribution for the PIB sulfonic acid 1 can be  
17 conveniently determined by any suitable technique such as negative ion  
18 electrospray ionization mass spectrometry.  
19  
20 Two PIB sultones have been identified in the reaction product of PIB with  $\text{SO}_3$ .  
21 These are a gamma sultone 2 and a delta sultone 3, which have the following  
22 structures:  
23



1 2  
2 Gamma Sultone



3

4 These products can be characterized by  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectroscopy. The  
 5 chemical shifts for the gamma sultone **2** can be assigned as follows:  $^1\text{H}$  NMR;  
 6 4.40 ppm (multiplet, 1H,  $\text{H}_\text{A}$ ), 1.60 ppm (multiplet, 2H, protons on  $\text{C}_4$ ).  
 7  $^{13}\text{C}$  NMR; 84.18 ppm (carbon  $\text{C}_3$  next to the O atom), 63.21 ppm (carbon  $\text{C}_1$ ,  
 8 next to  $\text{SO}_2$  group). The chemical shifts for the delta sultone **3** can be  
 9 assigned as follows:  $^1\text{H}$  NMR; 4.50 ppm (1H, triplet,  $J=3.9$  Hz,  $\text{H}_\text{B}$ ), 3.00 and  
 10 2.90 ppm (2H, multiplet, protons on carbon  $\text{C}_5$  next to the  $\text{SO}_2$ ), 2.28 ppm (1H,  
 11 multiplet,  $\text{H}_\text{C}$  proton on carbon  $\text{C}_6$ ).  $^{13}\text{C}$  NMR; 90.04 ppm (carbon  $\text{C}_8$  next to  
 12 the oxygen atom), 50.82 ppm (carbon  $\text{C}_5$  next to  $\text{SO}_2$  group). Minor amounts  
 13 of other PIB sultones may also be present in the mixture.

15 The relative amounts of PIB sulfonic acid, PIB sulfone, and recovered PIB in  
16 the PIB sulfonic acid mixture depends on the reaction conditions used during  
17 the sulfonation of the PIB with  $\text{SO}_3$ . Important process parameters include the  
18 feed temperature, the  $\text{SO}_3/\text{PIB}$  CMR, the flow rates, the residence time and  
19 space velocity, the reactor temperature, the viscosity of the feed, the film  
20 thickness, the amount of diluent, and the presence of added modifiers, such  
21 as carboxylic acid.

23 Surprisingly, the PIB sulfonic acids were found to be more sensitive to  
24 temperature than other sulfonic acids such as alkylbenzene sulfonic acids. At  
25 elevated temperatures, the PIB sulfonic acids react to form recovered PIB and  
26 sulfuric acid, fragment to lower molecular weight PIB sulfonic acids, and  
27 rearrange to PIB sultones. It is important to optimize the important process

1 parameters listed above in order to increase the total yield of PIB sulfonic acid  
2 in the mixture.

3

4 To increase the sulfonic acid yield and to decrease the quantity of sultones in  
5 the product, the reaction effluent is stabilized with a neutralizing agent as the  
6 reaction product exits a first reaction vessel (that is, the sulfonation reactor)  
7 and prior to or concurrently with entering a second vessel which is used for  
8 further reaction or storage. Suitable neutralizing agents include alkaline earth  
9 metal hydroxides and overbased detergents, for example, a moderate or high  
10 overbased detergent. A preferred neutralizing agent is an alkaline earth metal  
11 hydroxide. More preferably, the neutralizing agent is calcium hydroxide. If  
12 the PIB sulfonic acid is not neutralized, then the reaction effluent, which  
13 comprises a mixture of PIB sulfonic acid, sulfuric acid, recovered PIB,  
14 sultones, and sulfur trioxide, continues to react resulting in increased sultones  
15 and fragmentation of the polyisobutene sulfonic acid. Neutralizing the product  
16 as it leaves the falling film reactor greatly improves the quality of the product  
17 by preventing breakdown of the sulfonic acid and by preventing formation of  
18 sultones. The resultant product typically contains less than 10% sultones and  
19 the percentage of PIB sulfonic acid fragmentation contained in the product is  
20 less than 20%. The reaction product is stabilized by neutralization to from  
21 about 30% to about 150%, preferably about 60% to about 100%, and most  
22 preferably from about 70% to about 90% neutralization. The neutralization  
23 can be carried out at a temperature of between 20°C and 150°C, preferably at  
24 a temperature from 50°C to 110°C, and most preferably at a temperature from  
25 60°C to 90°C. The time between when the PIB sulfonic acid leaves the first  
26 reactor and is stabilized by neutralization should be between 2 seconds and  
27 one hour, preferably between 10 seconds and 10 minutes. The neutralization  
28 reaction itself should take place for a period of time from 10 minutes to  
29 10 hours, preferably 30 minutes to 7 hours, and most preferably 45 minutes to  
30 5 hours.

31

1 Two titration methods are used to characterize sulfonic acids and/or sulfonic  
2 acids stabilized by partial or complete neutralization: (1) the Cyclohexylamine  
3 titration method and (2) the Hyamine titration method. The Cyclohexylamine  
4 titration method is a potentiometric method that measures the percent Sulfuric  
5 Acid, percent Sulfonic Acid, percent Ca as Sulfonate, and acid number of a  
6 sulfonic acid sample as reported in the *Journal of American Oil Chemist  
7 Society*, Volume 55, page 359 (1978) by S. Yamaguchi (ASTM D 4711  
8 method). The Hyamine titration method is a colorimetric method that  
9 determines the percent Ca Sulfonate and the percent Hyamine Actives or  
10 HAT (Hyamine Actives Technique) which is calculated from the % Ca  
11 Sulfonate and is comparable to the % Sulfonic Acid value determined from the  
12 Cyclohexylamine titration method in both sulfonic acid and partially or fully  
13 neutralized sulfonic acid samples (ASTM D 3049 Method). The  
14 Cyclohexylamine titration measures all the sulfonic acids present in a sample  
15 regardless of their molecular weight. The Hyamine method only measures  
16 higher molecular weight (C10+ alkyl aromatic and C14+ alpha sulfonic acids  
17 or sulfonates) sulfonic acids or partially neutralized or fully neutralized  
18 sulfonate samples.

19  
20 Figure 1 shows the % Ca as Sulfonate and % Sulfuric Acid levels determined  
21 by the Cyclohexylamine Titration Method for an untreated PIB sulfonic acid  
22 prepared by the SO<sub>3</sub>/Air sulfonation of 550 MW PIB as a function of time when  
23 stored at 40°C (104°F). The data in Figure 1 is the average of two samples.

24 The samples were stored at room temperature until the thermal stability study  
25 was begun. Thereafter, samples were maintained at temperature in an oven  
26 and samples were titrated approximately every 3 days for approximately  
27 4 weeks. It is observed that the polyisobutene sulfonic acid % Ca as  
28 Sulfonate decreases with time and the % sulfuric acid content increases over  
29 a period of weeks.

30

31 Figure 2 shows a comparison of the % Ca Sulfonate determined by the  
32 Hyamine titration method of unstabilized PIB Sulfonic acid stored at 40°C

1 (104°F) and 60°C (140°F). The samples were stored at room temperature  
2 until the thermal stability study was begun. Thereafter, samples were  
3 maintained at temperature in an oven and samples were titrated  
4 approximately every 3 days for up to about 5 weeks. The data in Figure 2 is  
5 the average of two samples at each temperature. The 40°C data is for a  
6 550 MW PIB sulfonic acid and the 60°C data is for a 450 MW PIB sulfonic  
7 acid. It is observed that the % Ca Sulfonate for both these unstabilized PIB  
8 sulfonic acids rapidly decreases within a week and then remains  
9 approximately constant.

10

11 The data in Figures 1 and 2 show that the polyisobutene sulfonic acid derived  
12 from SO<sub>3</sub>/Air sulfonation is not thermally stable and the amount of the desired  
13 PIB sulfonic acid decreases when stored at moderate temperatures (40°C and  
14 60°C).

15

16 By contrast, Figure 3 shows the % Ca Sulfonate (determined by the Hyamine  
17 titration method) for PIB Sulfonic acid prepared by SO<sub>3</sub>/Air sulfonation  
18 followed by stabilization of the PIB sulfonic acid by neutralization (with lime  
19 slurry) as a function of time when stored at 40°C (104°F) and 60°C (140°F).  
20 The samples were stored at room temperature until the thermal stability study  
21 was begun. Thereafter, the samples were maintained at temperature in an  
22 oven and samples were titrated approximately every 3 days for up to  
23 approximately seven weeks. The data shown in Figure 3 is the average of  
24 two or more samples and the 60°C data is for stabilized 450 MW PIB sulfonic  
25 acid and the 40°C data is for stabilized 550 MW PIB sulfonic acid. It is  
26 observed that the % Ca Sulfonate of the stabilized PIB sulfonic acids remains  
27 approximately constant for at least 21 days at 40°C and 60°C.

28

29 Accordingly, Figure 3 demonstrates that the amount of PIB sulfonic acid is  
30 more stable when the sample has been stabilized by neutralization compared  
31 to when the PIB sulfonic acid has not been stabilized by neutralization (see  
32 Figures 1 and 2).

1 If samples of PIB sulfonic acid prepared by sulfonation with sulfur trioxide/air  
2 are not stabilized, the sultone levels can increase upon storage even at room  
3 temperatures.  
4  
5 The sultones in a sample of 550 MW polyisobutene sulfonic acid, prepared by  
6  $\text{SO}_3/\text{Air}$  sulfonation of the example herein below, were isolated by column  
7 chromatography and found to be present at 22.0 wt% in the unstabilized PIB  
8 sulfonic acid. If the 550 MW polyisobutene sulfonic acid is stabilized by  
9 neutralization with a slurry of lime in oil immediately following  $\text{SO}_3/\text{Air}$   
10 sulfonation, the level of sultones isolated by chromatography was 11.7 wt%.  
11 Thus, another advantage of the present invention is the reduction in the  
12 amount of sultones present in the polyisobutene sulfonic acid produced by  
13  $\text{SO}_3/\text{Air}$  sulfonation stabilized by neutralization of the PIB sulfonic acid which  
14 increases the amount of PIB sulfonic acid in the sample.  
15  
16 Another aspect of the present invention is a process for making a stabilized  
17 polyisobutene sulfonic acid product having reduced amounts of fragmentation  
18 products. Figure 4 shows the negative ion electrospray mass spectrum  
19 (ESMS) of an unstabilized 550 MW polyisobutene sulfonic acid produced by  
20  $\text{SO}_3/\text{Air}$  sulfonation. The peak at m/e 190 is the  $\text{C}_8$  sulfonic acid and the peak  
21 at m/e 247 is the  $\text{C}_{12}$  sulfonic acid. The  $\text{C}_8$  and  $\text{C}_{12}$  sulfonic acids result from  
22 fragmentation reactions. Figure 5 shows the ESMS of a 550 MW PIB sulfonic  
23 acid stabilized by neutralization with a slurry of lime in oil. The PIB sulfonic  
24 acid in Figure 5 was produced by  $\text{SO}_3/\text{Air}$  sulfonation. Comparing Figures 4  
25 and 5, stabilization of the PIB sulfonic acid by neutralization results in lower  
26 amounts of the  $\text{C}_8$  and  $\text{C}_{12}$  PIB sulfonic acids which are formed by  
27 fragmentation reactions.  
28  
29 Table I summarizes the results obtained by ESMS analysis of several  
30 550 MW PIB sulfonic acids produced by  $\text{SO}_3/\text{Air}$  sulfonation stabilized by  
31 neutralization with a lime-oil slurry and an unstabilized 550 MW PIB sulfonic  
32 acid. Table I shows the effect of stabilizing the PIB sulfonic acid with different

1 degrees of neutralization and the manner of neutralization (batch or inline) on  
2 the amount of C<sub>8</sub> and C<sub>12</sub> PIB acids present in the sample. The data in Table I  
3 show that in order to stabilize the PIB sulfonic acid by neutralization, complete  
4 neutralization is not necessary and that there is no difference between batch  
5 neutralization and inline neutralization.

6

7

Table I

8 Comparison of the Fragmentation of Unstabilized  
9 with Stabilized 550 MW PIB Sulfonic Acids  
10 by Negative Ion Electrospray Mass Spectrometry (ESMS)

Sample	Degree of Neutralization (%)	Manner of Neutralization	Weight % C <sub>8</sub> PIB Sulfonic Acid	Weight % C <sub>12</sub> PIB Sulfonic Acid
1	0	None	12.0	4.7
2	36.4	Inline	1.1	1.2
3	58.3	Batch	1.3	0.6
4	58.3	Inline	1.0	1.4
5	78.6	Inline	2.1	0.7
6	87.4	Inline	1.4	1.5
7	101.9	Inline	2.2	0.6
8	116.5	Inline	2.2	1.1

11

12 Another embodiment of the present invention is a reaction product that  
13 comprises stabilized PIB sulfonic acid, recovered PIB, fragmented  
14 polyisobutene molecules and sultones. Preferred percentages of  
15 fragmentation of the PIB sulfonic acid is less than 15%. Preferred  
16 percentages of sultones in the polyalkene sulfonic acid are less than 15%.  
17 More preferred percentages of sultones in the polyalkene sulfonic acid are  
18 less than 10%. Most preferred percentages of sultones in the polyalkene  
19 sulfonic acid are less than 5%.

20

1 Another embodiment of the present invention is a process for making a  
2 polyisobutene sulfonic acid product having reduced fragmentation and  
3 decreased sultone formation. In a reaction vessel, the process comprises  
4 diluting PIB feedstock with a diluent, prior to reacting polyisobutene having a  
5 number average molecular weight of from about 300 to about 1000 with a  
6 source of sulfur trioxide. The amount of diluent added to the PIB feedstock is  
7 typically up to 30% by weight. Group 2 base oils and non-aromatic solvents,  
8 such as heptane, are examples of suitable diluents. Diluting the PIB has two  
9 effects on the product. First, dilution of PIB reduces the viscosity (i.e., the PIB  
10 is less viscous) of the starting material, which improves the film quality of the  
11 PIB that attaches to the falling film reactor. Second, dilution of PIB acts as a  
12 heat sink which absorbs excess heat generated when the PIB reacts with  
13 sulfur trioxide. Fragmentation of the PIB sulfonic acid is affected by  
14 temperature. An increase in fragmentation is attributed to the increased  
15 temperature of the PIB when it reacts with sulfur trioxide. However, heating  
16 the reactor feed is necessary to minimize viscosity, which in turn improves the  
17 film quality inside the reactor. Diluting PIB with a neutral, low viscosity diluent  
18 improves film quality and minimizes the necessity of heating the reactor feed,  
19 thereby decreasing PIB molecule fragmentation. In addition, because the  
20 diluent acts as a heat sink, excess heat generated by the exothermic  
21 reactions is absorbed by the diluent. After the addition of the diluent, the  
22 diluted PIB is reacted with sulfur trioxide. The reaction product of diluted PIB  
23 and sulfur trioxide is stabilized with a neutralizing agent as the reaction  
24 product exits a first reaction vessel and prior to or concurrently with entering a  
25 second vessel which is used for further reaction or storage. The resultant  
26 product typically yields less than or equal to 15% fragmentation of the PIB  
27 sulfonate.

28

29 In another embodiment of the present invention, a small concentration of  
30 carboxylic acid is added to PIB feedstock prior to reacting the PIB with SO<sub>3</sub>.  
31 Preferably, carboxylic acids include formic acid, acetic acid, butyric acid or  
32 benzoic acid. More preferably, the carboxylic acid is acetic acid. In a reaction

1 vessel, a small concentration of acetic acid is added to the PIB feedstock,  
2 which may or may not be diluted with a diluent. The number average  
3 molecular weight of the PIB feedstock is generally from about 300 to about  
4 1000. Preferably, an amount less than or equal to 10% by weight of acetic  
5 acid is added to the PIB feedstock. More preferably, an amount less than or  
6 equal to 5% by weight is added to the PIB feedstock. Most preferably, an  
7 amount less than or equal to 3% by weight is added to the PIB feedstock.  
8 The mixture comprising the PIB feedstock containing acetic acid is then  
9 reacted with a source of SO<sub>3</sub> as previously described. The reaction product of  
10 the PIB and SO<sub>3</sub> is stabilized with a neutralizing agent as the reaction product  
11 exits a first reaction vessel and prior to or concurrently with entering a second  
12 vessel which is used for further reaction or storage. PIB sulfonic acid  
13 fragmentation of the resultant reaction product is typically dependent upon the  
14 molecular weight of the PIB feedstock. At a maximum, the stabilized PIB  
15 sulfonic acid fragmentation is typically less than 15%.

16

17 In another embodiment of the present invention, the dilution of the PIB  
18 feedstock and the addition of the carboxylic acid, preferably acetic acid, may  
19 be combined with the stabilization by neutralization step after reaction of the  
20 PIB feedstock with SO<sub>3</sub>. Accordingly, carboxylic acid is added to the PIB  
21 feedstock which is diluted with a diluent and then reacted with a source of  
22 SO<sub>3</sub>. The reaction product is then stabilized with a neutralizing agent, such as  
23 calcium hydroxide, as the product exits a first reaction vessel and prior to or  
24 concurrently with entering a second vessel used for further reaction or  
25 storage, thereby producing a product that has a low amount of sulfones and  
26 reduced fragmentation of the stabilized PIB sulfonic acid.

27

28 In another embodiment of the present invention, a product may be made by  
29 the processes as described above.

30

1    Overbasing

2

3    In another embodiment of this invention, the stabilized polyalkenyl sulfonic  
4    acids that are prepared by the process of the present invention may be further  
5    processed by overbasing procedures to produce overbased sulfonates.  
6    Overbased materials are characterized by a metal content in excess of that  
7    which would be present according to the stoichiometry of the metal cation in  
8    the sulfonate said to be overbased. Thus, a monosulfonic acid when  
9    neutralized with an alkaline earth metal compound (or an alkaline earth metal  
10   basic salt), more preferably using a calcium compound, most preferably using  
11   calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ), will produce a normal sulfonate containing one  
12   equivalent of calcium for each equivalent of acid. In other words, the normal  
13   metal sulfonate will contain one mole of calcium for each two moles of the  
14   monosulfonic acid.

15

16    The amount of overbasing can be expressed as a Total Base Number  
17   ("TBN"), which refers to the amount of base equivalent to one milligram of  
18   KOH in one gram of sulfonate. Thus, higher TBN numbers reflect more  
19   alkaline products and therefore a greater alkalinity reserve. The TBN for a  
20   composition is readily determined by ASTM test method D2896 or other  
21   equivalent methods. The preferred overbased polyalkenyl sulfonates of this  
22   invention have relatively low TBN, i.e., from about greater than 0 to about 100.

23

24    Overbasing procedures for relatively low TBN sulfonates are described in  
25   many patents including Le Coent, U.S. Patent No. 4,764,295 and Alcock  
26   et al., U.S. Patent No. 5,789,615, which are herein incorporated by reference.  
27   Known overbasing art for low overbased (LOB) sulfonates generally employ  
28   promoters such as  $\text{CaCl}_2$  and carboxylic acids in the presence of a solvent  
29   such as 2-ethylhexanol or toluene. In the present invention, the stabilized  
30   polyalkenyl, preferably polybutenyl, sulfonic acids which have been prepared  
31   by the methods described previously are preferably overbased using only  
32   water as a promoter. A further aspect of the invention includes adding  $\text{CaCl}_2$ ,

1 but it is not required to produce a product with acceptable properties. The  
2 amount of water used for overbasing is in the range of 0.5 to 8.0 wt% of the  
3 total stabilized PIB sulfonic acid, more preferably in the range of 0.75 to  
4 3.00 wt%. In a further embodiment of this invention, the overbasing step is  
5 conducted at much higher temperatures and pressures than previously known  
6 in the art. The overbasing temperature is from 100°C to 170°C, preferably  
7 110°C to 150°C, while the pressure during the overbasing step ranges 15 to  
8 65 psia, more preferably from 16 to 50 psia. Overbasing can also be  
9 accomplished by refluxing water at ambient pressures and temperatures from  
10 about 100°C to about 150°C, more preferably from about 110°C to about  
11 130°C, and most preferably from about 115°C to about 130°C.

12

13 The overbasing conditions described herein may be utilized to overbase both  
14 stabilized and unstabilized polyalkenyl sulfonic acids.

15

#### 16 Lubricating Oil Compositions

17

18 The polyalkenyl sulfonates made by the process of this invention are useful as  
19 additives in lubricating oils. They have good tolerance to water, a light color,  
20 and provide good performance characteristics.

21

22 The lubricating oil compositions, which may be made by the process of this  
23 invention, comprise a major amount of an oil of lubricating viscosity and a  
24 minor amount of the polyalkenyl sulfonates of this invention. The oils can be  
25 derived from petroleum or be synthetic. The oils can be paraffinic,  
26 naphthenic, halosubstituted hydrocarbons, synthetic esters, or combinations  
27 thereof. Oils of lubricating viscosity have viscosities in the range from 35 to  
28 55,000 SUS at 100°F, and more usually from about 50 to 10,000 SUS at  
29 100°F. The lubricating oil compositions contain an amount of the polyalkenyl  
30 sulfonates of this invention sufficient to provide dispersant properties, typically  
31 from about 0.1 wt% to 10 wt%, preferably from about 0.5 wt% to about 7 wt%.

32

1 Other conventional additives that can be used in combination with the  
2 polyalkenyl sulfonates of this invention include oxidation inhibitors, antifoam  
3 agents, viscosity index improvers, pour point depressants, dispersants and  
4 the like.

5

6 The lubricating oil compositions made by the process of this invention are  
7 useful for lubricating internal combustion engines and automatic  
8 transmissions, and as industrial oils such as hydraulic oils, heat transfer oils,  
9 torque fluids, etc.

10 When used as detergents or dispersants, these additives may be used at  
11 about 0.2 wt% to about 10 wt% of the total lubricating oil composition and  
12 preferably at about 0.5 wt% to about 8 wt%, and more preferably at about  
13 1 wt% to about 6 wt% of the total lubricating oil composition.

14

15 The lubricating oil used with these additive compositions may be mineral oil or  
16 synthetic oils of lubricating viscosity and preferably suitable for use in the  
17 crankcase of an internal combustion engine. Crankcase lubricating oils  
18 ordinarily have a viscosity of about 1300 cSt at 0°F (-18°C) to 22.7 cSt at  
19 210°F (99°C). The lubricating oils may be derived from synthetic or natural  
20 sources. Hydrocarbon synthetic oils may include, for example, oils prepared  
21 from the polymerization of ethylene, polyalphaolefin or PAO oils, or oils  
22 prepared from hydrocarbon synthesis procedures using carbon monoxide and  
23 hydrogen gases such as in a Fisher-Tropsch process. Mineral oil for use as  
24 the base oil in this invention may include paraffinic, naphthenic and other oils  
25 that are ordinarily used in lubricating oil compositions. Synthetic oils include  
26 both hydrocarbon synthetic oils and synthetic esters. Useful synthetic  
27 hydrocarbon oils include liquid polymers of alpha olefins having the proper  
28 viscosity. The hydrogenated liquid oligomers of C<sub>6</sub> to C<sub>12</sub> alpha olefins such  
29 as 1-decene trimer are especially useful. Alkyl benzenes of proper viscosity,  
30 such as didodecyl benzene, may also be used.

31

1    Hydrocarbon oils blended with synthetic oils may also be useful. For  
2    example, blends of 10 to 25 wt% hydrogenated 1-decene trimer with 75 to  
3    90 wt% 150 SUS (100°F) mineral oil are preferred as a lubricating oil base.  
4  
5    Another embodiment of the present invention is lubricating oil concentrates.  
6    These concentrates usually include from about 90 wt% to about 10 wt%,  
7    preferably from about 90 wt% to about 50 wt%, of an oil of lubricating viscosity  
8    and from about 10 wt% to about 90 wt%, preferably from about 10 wt% to  
9    about 50 wt%, of the additives described herein. Typically, the concentrates  
10   contain sufficient diluent to make them easy to handle during shipping and  
11   storage. Suitable diluents for the concentrates include any inert diluent,  
12   preferably an oil of lubricating viscosity, so that the concentrate may be  
13   readily mixed with lubricating oils to prepare lubricating oil compositions.  
14   Suitable lubricating oils that may be used as diluents typically have viscosity  
15   in the range from about 35 to about 500 Saybolt Universal Seconds (SUS) at  
16   100°F (38°C), although any oil of lubricating viscosity may be used.  
17

18   Other additives that may be used include rust inhibitors, foam inhibitors,  
19   corrosion inhibitors, metal deactivators, pour point depressants, antioxidants,  
20   and a variety of other well-known additives.

21

22   Other Additives

23

24   The following additive components are examples of some of the components  
25   that can be favorably employed in the present invention. These examples of  
26   additives are provided to illustrate the present invention, but they are not  
27   intended to limit it:

28   1.   Metal Detergents

29       Sulfurized or unsulfurized alkyl or alkenyl phenates, alkyl or alkenyl  
30       aromatic sulfonates, sulfurized or unsulfurized metal salts of  
31       multi-hydroxy alkyl or alkenyl aromatic compounds, alkyl or alkenyl  
32       hydroxy aromatic sulfonates, sulfurized or unsulfurized alkyl or alkenyl

1 naphthenates, metal salts of alkanoic acids, metal salts of an alkyl or  
2 alkenyl multiacid, and chemical and physical mixtures thereof.  
3

4 2. Anti-Oxidants  
5 Anti-oxidants reduce the tendency of mineral oils to deteriorate in  
6 service which deterioration is evidenced by the products of oxidation  
7 such as sludge and varnish-like deposits on the metal surfaces and by  
8 an increase in viscosity. Examples of anti-oxidants useful in the  
9 present invention include, but are not limited to, phenol type (phenolic)  
10 oxidation inhibitors, such as 4,4'-methylene-bis(2,6-di-tert-butylphenol),  
11 4,4'-bis(2,6-di-tert-butylphenol),  
12 4,4'-butyldene-bis(2-methyl-6-tert-butylphenol),  
13 2,2'-methylene-bis(4-methyl-6-tert-butylphenol),  
14 4,4'-butyldene-bis(3-methyl-6-tert-butylphenol),  
15 4,4'-isopropylidene-bis(2,6-di-tert-butylphenol),  
16 2,2'-methylene-bis(4-methyl-6-nonylphenol),  
17 2,2'-isobutylidene-bis(4,6-dimethylphenol), 2,2'-5  
18 methylene-bis(4-methyl-6-cyclohexylphenol),  
19 2,6-di-tert-butyl-4-methylphenol, 2,6-di-tert-butyl-4-ethylphenol,  
20 2,4-dimethyl-6-tert-butyl-phenol, 2,6-di-tert-l-dimethylamino-p-cresol,  
21 2,6-di-tert-4-(N,N'-dimethylaminomethylphenol),  
22 4,4'-thiobis(2-methyl-6-tert-butylphenol),  
23 2,2'-thiobis(4-methyl-6-tert-butylphenol), bis(3-methyl-4-hydroxy-5-tert-  
24 10-butylbenzyl)-sulfide, and bis(3,5-di-tert-butyl-4-hydroxybenzyl).  
25 Diphenylamine-type oxidation inhibitors include, but are not limited to,  
26 alkylated diphenylamine, phenyl-alpha-naphthylamine, and alkylated-  
27 alpha-naphthylamine. Other types of oxidation inhibitors include metal  
28 dithiocarbamate (e.g., zinc dithiocarbamate), and  
29 methylenebis(dibutylthiocarbamate). The anti-oxidant is generally  
30 incorporated into an engine oil in an amount of about 0 to 10 wt%,  
31 preferably 0.05 to 3.0 wt%, per total amount of the engine oil.  
32

1    3.    Anti-Wear Agents

2        As their name implies, these agents reduce wear of moving metallic  
3        parts. Examples of such agents include, but are not limited to,  
4        phosphates, carbamates, esters, and molybdenum complexes.

5

6    4.    Rust Inhibitors (Anti-Rust Agents)

7        (a) Nonionic polyoxyethylene surface active agents: polyoxyethylene  
8            lauryl ether, polyoxyethylene higher alcohol ether,  
9            polyoxyethylene nonyl phenyl ether, polyoxyethylene octyl phenyl  
10          ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl  
11          ether, polyoxyethylene sorbitol monostearate, polyoxyethylene  
12          sorbitol mono-oleate, and polyethylene glycol mono-oleate.

13

14        (b) Other compounds: stearic acid and other fatty acids, dicarboxylic  
15          acids, metal soaps, fatty acid amine salts, metal salts of heavy  
16          sulfonic acid, partial carboxylic acid ester of polyhydric alcohol,  
17          and phosphoric ester.

18

19    5.    Demulsifiers

20        Addition product of alkylphenol and ethylene oxide, polyoxyethylene  
21          alkyl ether, and polyoxyethylene sorbitan ester.

22

23    6.    Extreme Pressure Anti-Wear Agents (EP/AW Agents)

24        Zinc dialkyldithiophosphate (primary alkyl, secondary alkyl, and aryl  
25          type), diphenyl sulfide, methyl trichlorostearate, chlorinated  
26          naphthalene, fluoroalkylpolysiloxane, lead naphthenate, neutralized  
27          phosphates, dithiophosphates, and sulfur-free phosphates.

28

29    7.    Friction Modifiers

30        Fatty alcohol, fatty acid, amine, borated ester, and other esters.

31

1    8. Multifunctional Additives  
2       Sulfurized oxymolybdenum dithiocarbamate, sulfurized  
3       oxymolybdenum organo phosphorodithioate, oxymolybdenum  
4       monoglyceride, oxymolybdenum diethylate amide, amine-molybdenum  
5       complex compound, and sulfur-containing molybdenum complex  
6       compound.  
7  
8    9. Viscosity Index Improvers  
9       Polymethacrylate type polymers, ethylene-propylene copolymers,  
10      styrene-isoprene copolymers, hydrated styrene-isoprene copolymers,  
11      polyisobutylene, and dispersant type viscosity index improvers.  
12   10. Pour Point Depressants  
13      Polymethyl methacrylate.  
14  
15   11. Foam Inhibitors  
16      Alkyl methacrylate polymers and dimethyl silicone polymers.  
17  
18   12. Metal Deactivators  
19      Disalicylidene propylenediamine, triazole derivatives,  
20      mercaptobenzothiazoles, and mercaptobenzimidazoles.  
21  
22   It is also contemplated that the additives described herein may be employed  
23   as dispersants and detergents in hydraulic fluids, marine crankcase lubricants  
24   and the like. When so employed, the additive is added from about 0.1 to 10%  
25   by weight to the oil. Preferably, the additive is added from 0.5 to 8 wt%.  
26

## SULFONATION EXAMPLES

### Example 1

### Effect of Stabilization by Neutralization On Sultone Formation

6 In a falling film reactor,  $\text{SO}_3$  in air was reacted with PIB having a Mn of  
7 550 MW using the following conditions:  $\text{SO}_3/\text{PIB}$  molar ratio = 1.015; feed  
8 temperature = 90°C; reactor temperature = 77.6°C;  $\text{SO}_3$  concentration in air =  
9 1.5%;  $\text{SO}_3$  loading = 0.371 kg/cm-hr;  $\text{SO}_3/\text{Air}$  gas inlet temperature = 50°C;  
10 PIB feed flow rate = 12.0 kg/hr;  $\text{SO}_3$  flow rate = 1.77 kg/hr. Immediately  
11 (within 5 seconds) after formation in the sulfonation reactor, the PIB sulfonic  
12 acid was stabilized by neutralization with a lime-oil slurry (10.6 wt%  $\text{Ca}(\text{OH})_2$   
13 in Group I 100N oil). The degree of neutralization was 145%. After mixing  
14 the PIB sulfonic acid with the lime slurry, the mixture was passed through an  
15 inline static mixer and then into a stirred tank neutralization vessel held at  
16 72°C. Chromatographic analysis of the stabilized product showed it to contain  
17 29.0 wt% recovered PIB, 11.7 wt% sulfones, and 59.2 wt% sulfonic acid.

### Comparative Example 1A

### Sultone Formation In A Non-Neutralized Acid

21 In a falling film reactor,  $\text{SO}_3$  was reacted with PIB having a  $M_n$  of 550 MW  
22 exactly as in Example 1, except that following sulfonation, the PIB sulfonic  
23 acid was not stabilized by neutralization. Analysis of this unstabilized,  
24 unneutralized PIB sulfonic acid by chromatography showed it to contain  
25 23.0 wt% recovered PIB, 22.0 wt% sulfones, and 51.0 wt% sulfonic acid.

### Example 2

## Effect of Stabilization by Neutralization and Oil Dilution of the PIB on Sultone Formation

5 In a falling film reactor,  $\text{SO}_3$  in air was reacted with a mixture of 70 wt% PIB  
6 having a Mn of 550 MW and 30 wt% oil (Group I 100 Neutral Oil) using the  
7 following conditions:  $\text{SO}_3/\text{PIB}$  molar ratio = 0.900; feed temperature = 90°C;  
8 reactor temperature = 67.5°C;  $\text{SO}_3$  concentration in air = 1.4 %;  $\text{SO}_3$  loading =  
9 0.347  $\text{kg}/\text{cm}^{-2}\text{hr}$ ;  $\text{SO}_3/\text{Air}$  gas inlet temperature = 50°C; PIB feed flow rate =  
10 18.10  $\text{kg}/\text{hr}$ ;  $\text{SO}_3$  flow rate = 1.66  $\text{kg}/\text{hr}$ . Immediately (within 5 seconds) after  
11 formation in the sulfonation reactor, the mixture of PIB sulfonic acid and oil  
12 was stabilized by neutralization with a lime-oil slurry (10.6 wt%  $\text{Ca}(\text{OH})_2$  in  
13 Group I 100N oil). The degree of neutralization was 145%. After mixing the  
14 PIB sulfonic acid with the lime slurry, the mixture was passed through an  
15 inline static mixer and then into a stirred tank neutralization vessel held at  
16 72°C. Chromatographic analysis of the stabilized product showed it to contain  
17 26.0% recovered PIB, 4.7% sulfones, and 69.3% sulfonic acid, correcting for  
18 the diluent oil.

### Comparative Example 2A

## Sultone Formation in a Non-Neutralized Acid and with Oil Dilution

23 In a falling film reactor,  $\text{SO}_3$  in air was reacted with a mixture of 70 wt% PIB  
24 having a Mn of 550 MW and 30 wt% oil (Group I 150 Neutral Oil) exactly as in  
25 Example 2, except that following sulfonation, the PIB sulfonic acid was not  
26 stabilized by neutralization. Analysis of this unstabilized, unneutralized PIB  
27 sulfonic acid by chromatography showed it to contain 21.2 wt% recovered  
28 PIB, 23.0 wt% sulfones, and 55.6 wt% sulfonic acid.

30 The results of Examples 1-2 and Comparative Examples 1A-2A are  
31 summarized in Table II.

1  
2  
3  
4  
5

Table II  
Comparison of Chromatographic Analytical Results  
for Stabilized (Neutralized) and Unstabilized (Non-Neutralized)  
550 MW PIB Sulfonic Acid

Sample	Recovered PIB (%)	Sultones (%)	PIB Sulfonic Acid (%)
<b>Example 1</b>			
Neutralized PIB Sulfonic Acid	29.0	11.7	59.2
<b>Comparative Example 1A</b>			
Non-Stabilized (Non-neutralized) PIB Sulfonic Acid	23.0	22.0	54.0
<b>Example 2</b>			
Diluted PIB and Stabilized (Neutralized) PIB Sulfonic Acid	26.0	4.7	69.3
<b>Comparative Example 2A</b>			
Diluted PIB and Non-Stabilized (Non-Neutralized) PIB Sulfonic Acid	21.2	23.0	55.6

6  
7  
8  
9

Example 3

Sulfonation of 450 MW PIB Using Optimized Conditions

10 In a falling film reactor,  $\text{SO}_3$  in air was reacted with PIB having a Mn of  
11 450 MW using the following conditions:  $\text{SO}_3/\text{PIB}$  molar ratio = 1.035; feed  
12 temperature = 75°C; reactor temperature = 60°C;  $\text{SO}_3$  concentration in air =  
13 4.0%;  $\text{SO}_3$  loading = 0.875 kg/cm-hr;  $\text{SO}_3/\text{Air}$  gas inlet temperature = 50°C;  
14 PIB flow rate = 22.74 kg/hr;  $\text{SO}_3/\text{Air}$  flow rate = 4.19 kg/hr. Immediately  
15 (within 5 seconds) after formation in the sulfonation reactor, the PIB sulfonic  
16 acid was stabilized by neutralization with a lime-oil slurry (25.0 wt% lime in oil)  
17 at a ratio of 0.21 pounds of slurry per pound of PIB acid at 55°C in an inline  
18 mixer. After mixing the PIB sulfonic acid with the lime slurry, the mixture was  
19 passed through an inline static mixer and then into a stirred tank vessel held  
20 at approximately 72°C. The degree of neutralization was 89%. Analysis of  
21 the resulting stabilized PIB sulfonic acid showed the following: % Ca

1 Sulfonate by Hyamine titration = 1.93; % Ca = 2.26; % S = 4.83, Viscosity =  
2 207 cSt (100°C).

3

4 Example 4

5 Large Scale Preparation of Stabilized 550 MW PIB Sulfonic Acid

6

7 In a falling film reactor, SO<sub>3</sub> in air was reacted with a mixture of 70 wt% PIB  
8 having a Mn of 550 MW and 30 wt% oil (Group 100 Neutral Oil) using the  
9 following conditions: SO<sub>3</sub>/PIB molar ratio = 0.825; feed temperature = 90°C;  
10 reactor temperature = 67.5°C; SO<sub>3</sub> concentration in air = 3.6%; SO<sub>3</sub> loading =  
11 0.800 kg/cm<sup>2</sup>hr; SO<sub>3</sub>/Air gas inlet temperature = 50°C; feed flow rate =  
12 41.4 kg/hr; SO<sub>3</sub> flow rate = 3.83 kg/hr. Immediately (within 5 seconds) after  
13 formation in the sulfonation reactor, the mixture of PIB sulfonic acid and oil  
14 was stabilized by neutralization with a lime-oil slurry (25.0 wt% Ca(OH)<sub>2</sub> in  
15 Group I 100N oil) at a ratio of 0.21 pounds of slurry per pound of product  
16 exiting the sulfonation reactor. The degree of neutralization was 87.4%. After  
17 mixing the PIB sulfonic acid/diluent oil with the lime slurry, the mixture was  
18 passed through an inline static mixer and then into a 5 gallon stirred tank  
19 neutralization vessel. Once the stirred tank neutralization vessel was full, it  
20 was replaced with another 5 gallon vessel and the previous 5 gallon vessel  
21 was stirred for an additional 30 minutes. A total of approximately 30 gallons  
22 of stabilized PIB sulfonic acid was prepared in this manner.

23

24 OVERBASING EXAMPLES

25

26 Example 5

27

28 A 3.5 liter autoclave was charged with 1824 grams of the stabilized 550 MW  
29 PIB sulfonic acid prepared according to Example 4. Then 7.5 grams of a 32%  
30 CaCl<sub>2</sub> solution and 40 grams of water were added to the autoclave along with  
31 45 grams of lime and 121 grams of 100N neutral oil with agitation. The  
32 autoclave was heated to 149°C over 1 hour and during this heatup, when the

1 temperature reached 45°C, the vent line on the autoclave was closed to  
2 prevent the escape of any water vapors. The autoclave was then held at  
3 149°C for 3 hours during which time the pressure in the autoclave rose to a  
4 maximum of 40 psia. After the three-hour hold, the autoclave was slowly  
5 vented to atmospheric pressure. The temperature was then raised to 160°C  
6 over 5 minutes and the pressure was reduced to approximately 0.4 psia.  
7 After holding the autoclave for 15 minutes at these conditions, the autoclave  
8 was pressurized to atmospheric pressure with nitrogen and the autoclave was  
9 cooled to room temperatures. The crude product had a sediment of  
10 0.4 volume %. The product was filtered and analysis of the filtered product  
11 showed it to have the following properties: TBN = 19, viscosity (at 100°C) =  
12 113 cSt, Chloride = 660 ppm, % Ca Sulfonate = 1.32 by the Hyamine titration  
13 method, Total % Ca = 2.4.

14

15 Example 6

16

17 The procedures described in Example 5 were repeated exactly except the  
18 autoclave was vented to atmosphere during the entire time the autoclave was  
19 at 149°C. The crude product had a sediment of 1.8 volume %. Analysis of  
20 the filtered product showed it to have the following properties: TBN = 8,  
21 viscosity = 215 cSt (100°C).

22

23 Example 7

24

25 The procedures described in Example 5 were repeated exactly except no  
26 water was added to the autoclave. The crude product had a sediment level of  
27 1.0 volume % and analysis of the filtered product showed it to have the  
28 following properties: TBN = 15, viscosity = 109 cSt (100°C).

29

1

### Example 8

?

3 The procedures described in Example 5 were repeated exactly and the water  
4 charge was 80 grams. The crude product had a sediment level of  
5 1.0 volume % and analysis of the filtered product showed it to have the  
6 following properties: TBN = 17, viscosity = 134 cSt (100°C).

7

8

### Example 9

8

10 The procedures described in Example 5 were repeated exactly except an  
11 autoclave temperature of 120°C was used instead of 149°C and the autoclave  
12 was held at 120°C for 5 hours instead of 149°C for 3 hours. The crude  
13 product had a sediment of 1.6 volume % and analysis of the filtered product  
14 showed it to have the following properties: TBN = 17, viscosity = 114 cSt  
15 (100°C).

16

### Example 10

17

18 A 10 gallon reactor was charged with 15998 grams of the stabilized 450 MW  
19 PIB sulfonic acid prepared in Example 3 followed by 5698 grams of diluent oil  
20 (Group I, 100N) followed by 614 grams of lime, 83 grams of a 35 wt%  $\text{CaCl}_2$   
21 aqueous solution, and 203 grams of water with agitation. As in Example 5,  
22 the reactor was heated to 149°C over 1 hour and when the reactor reached  
23 52°C, the reactor vent line was closed and the reactor was held at 149°C for  
24 3 hours during which the reactor pressure increased to 29 psia. After 3 hours,  
25 the reactor was slowly vented to atmospheric pressure and then the pressure  
26 was then decreased to 1 psia. The reactor was held 149°C and 1 psia for  
27 30 minutes. The reactor pressure was then increased to atmospheric  
28 pressure with nitrogen and cooled to ambient temperature. Following  
29 filtration, analysis of the final product showed to have the following properties:  
30 TBN = 22, viscosity = 106 cSt (100°C), Chloride = 859 ppm, % Calcium =  
31 3.05, % Ca Sulfonate = 1.65 by the Hyamine titration method.

32

## CHROMATOGRAPHY EXAMPLE

### Example 11

## Isolation of Sultones by Chromatography

6 The following is an example of the chromatographic procedure used to isolate  
7 the sultones from stabilized and unstabilized PIB sulfonic acid. The product  
8 from Example 2, 4.05 grams, was dissolved in approximately 30 mls of  
9 hexane and placed on a chromatography column (75 ml column volume  
10 containing 10 gms of silica gel obtained from Alltech Corporation, Part  
11 Number 139310). The column was then eluted with successive volumes of  
12 solvent and three fractions were collected, concentrated by removal of the  
13 solvent and the material isolated in the fractions was then weighed. The  
14 following results were obtained: Fraction 1, 100 mls hexane, 1.93 gms  
15 consisting of 1.21 gms of oil and 0.72 gms (26 wt% based on PIB) of  
16 recovered PIB; Fraction 2, 100 mls 50:50 by volume toluene: dichloromethane,  
17 0.13 gms of sultones (4.7 wt%); Fraction 3, 100 mls methanol, 1.92 gms of  
18 PIB sulfonic acid, (69.3 wt%).